

JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

Topic: EVA Physiology & Medical Considerations Working in the Suit

Date: January 24, 2012

Location: Johnson Space Center (JSC), Houston, TX

Presenter: Scott Parazynski, M.D.

Synopsis: This “EVA Physiology & Medical Considerations Working in the Suit” presentation covers several topics related to the medical implications and physiological effects of suited operations in space from the perspective of a physician with considerable first-hand Extravehicular Activity (EVA) experience. Key themes include EVA physiology – working in a pressure suit in the vacuum of space, basic EVA life support and work support, Thermal Protection System (TPS) inspections and repairs, and discussions of the physical challenges of an EVA. Parazynski covers the common injuries and significant risks during EVAs, as well as physical training required to prepare for EVAs. He also shares overall suit physiological and medical knowledge with the next generation of Extravehicular Mobility Unit (EMU) system designers.

Biography: Dr. Scott Parazynski is a physician and a physiologist with expertise in human adaptation to stressful environments, having been graduated from Stanford University and Stanford Medical School. He went on to train at Harvard University and in Denver in preparation for a career in emergency medicine and trauma. In 1992 he was selected to join NASA’s Astronaut Corps and eventually flew five Space Shuttle missions and conducted seven spacewalks (EVAs). In October 2007, Parazynski led the EVA team on STS-120, a highly complex space station assembly flight, during which he performed four EVAs. The fourth and final EVA is regarded by many as one of the most challenging and dangerous ever performed. In his 17 years as an astronaut, he also served in numerous senior leadership roles, including EVA branch chief and the lead astronaut for Space Shuttle Thermal Protection System Inspection & Repair (in the aftermath of the Space Shuttle Columbia tragedy). He has the distinction of being the only person to both fly in space and stand on top of the planet, the summit of 29,035-foot Mount Everest. He served as chief technology officer and chief medical officer at The Methodist Hospital Research Institute in Houston, Texas.

Video Length and Size: 1:36:32 (1.59 GB)

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EVA Physiology & Medical Considerations Working in the Suit



Scott Parazynski, MD

“US Spacesuit Knowledge Capture Series”

24 January 2012

www.parazynski.com



Please
Silence
Your
Cell Phone



"US Spacesuit Knowledge Capture Series"

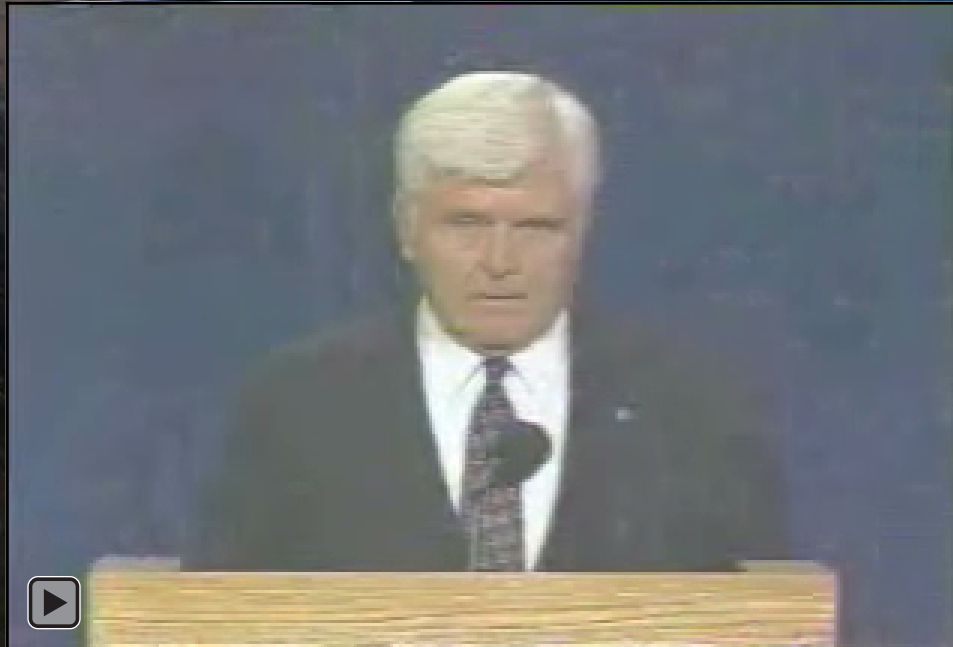
1. "EVA Physiology & Medical Considerations Working in a Suit" --- Tuesday, January 24, 2012

YOU ARE
HERE

we all are



Sir, you're no ~~Jack Kennedy~~ Admiral Stockdale!



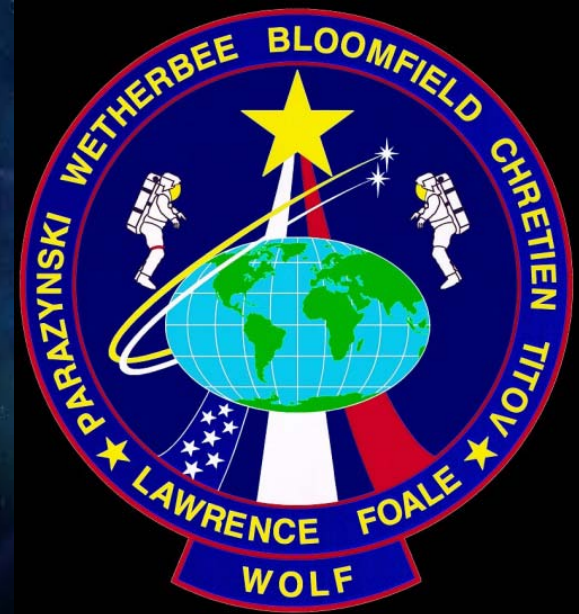
Admiral James Stockdale

1992

Vice Presidential Debate

“Parazynski” is like “Smith” or “Doe” in Poland...







Human Complexity

**HUMANS ARE EVEN MORE
COMPLEX THAN THE
SPACECRAFT YOU'RE
BUILDING**

Height

Weight

Fast vs. Slow Twitch

Strength

Visual Acuity

Mechanical
Aptitude

Native Language

Underlying Medical
Conditions

Susceptibility
to SAS

Arm Reach

Pain (Discomfort)
Tolerance

Cultural
Differences

G-Tolerance

Handedness

Situational
Awareness

Gender

Auditory Acuity

Depth of Knowledge
(Preparedness)

Operational
Background

Reaction Time
(Scan Pattern)

Endurance

Verbal Clarity &
Fluency

Lessons Learned on the Job



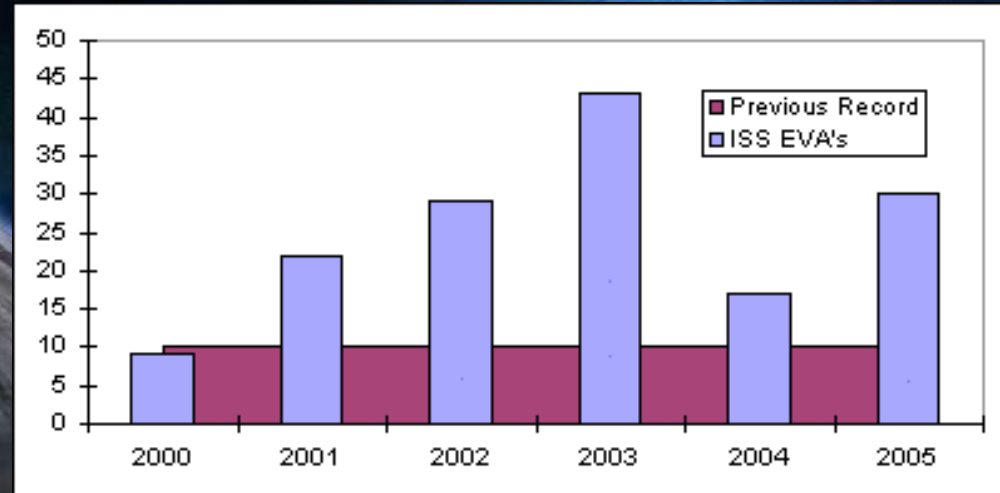
- “EVA Cadre” selected to do the majority of development testing
- Led to acceptance of some hardware and tasks that could not be accomplished by a broad cross section of the Astronaut Corps
- Once recognized as an issue, crew consensus testing became actively more inclusive

Fluid “Quick Disconnects”



Wall of EVA: Summit Success

- ISS “Wall of EVA”: not enough qualified crew for the volume of work ahead
- Developed the “EVA Skills Training Program”
 - Defined “Gold Standards” of EVA performance
 - Gave trainees additional time to work towards these goals
 - Ultimately a huge success: ISS assembly complete, many maintenance successes by ISS crews



Human-Centered Design

**Requirements & Design Phase
w/Experienced Crew Input**

**Test & Validation
w/Experienced Crew Input**

**Procedure & Ops Concept
Development w/Experienced
Crew Involvement**

**Successful Flight Operations &
Maintenance in Concert w/Crew**

- **Crew Evaluators Should Include:**
 - Broad Range of Anthropometrics
 - Matching Skill & Experience Levels of Anticipated Crews
- **Early Crew Input:**
 - Saves Time Pre-Flight
 - Saves \$\$\$
 - Increases On-Orbit Efficiency
 - Enhances Maintenance Capability On-Orbit

Space Medicine 101



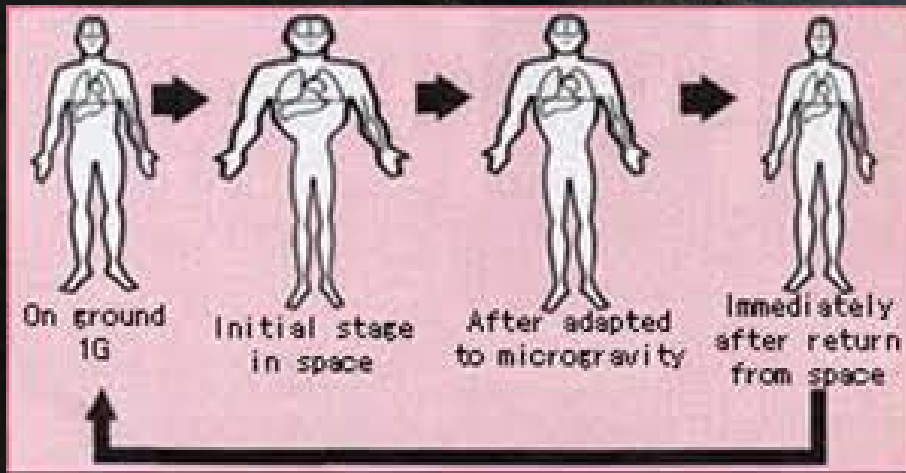
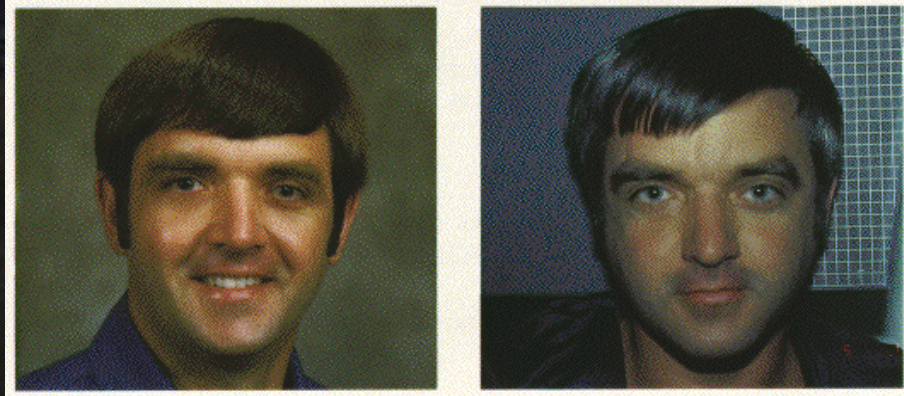
- Wide Variability in Adaptation to 0-G
 - Motion Sickness
 - Fluid Shifts
 - Back Pain
- Med Kit Contents & Exercise: Based on Probabilistic Risk Assessments
- Return to 1-G Physically More Challenging
 - Neurovestibular
 - Musculoskeletal
 - Cardiovascular

Space Adaptation Syndrome

- SAS, a.k.a. Space Motion Sickness
- Generally Limited to First 1-2 Days On-Orbit
- Otoliths “Unweighted”
- Preemptive Meds Helpful (Phen-Dex)
- Avoid Rapid Head Motions on Arrival
- Treat with Intramuscular Phenergan at Bedtime



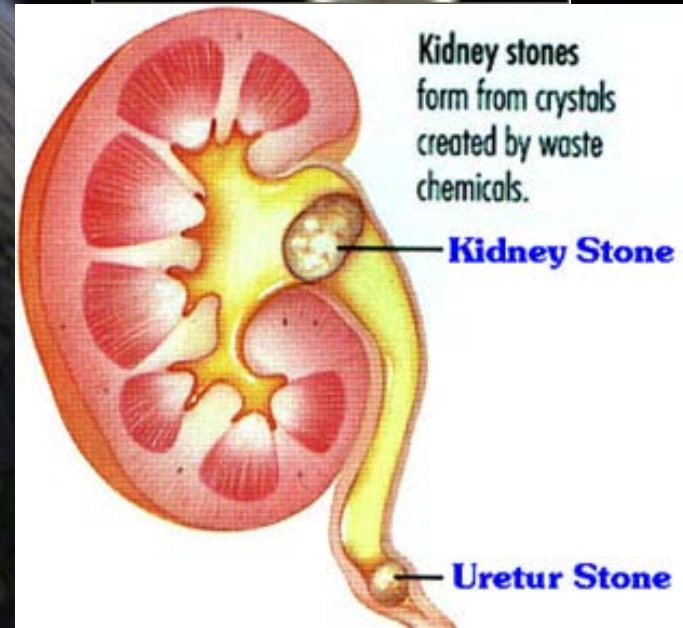
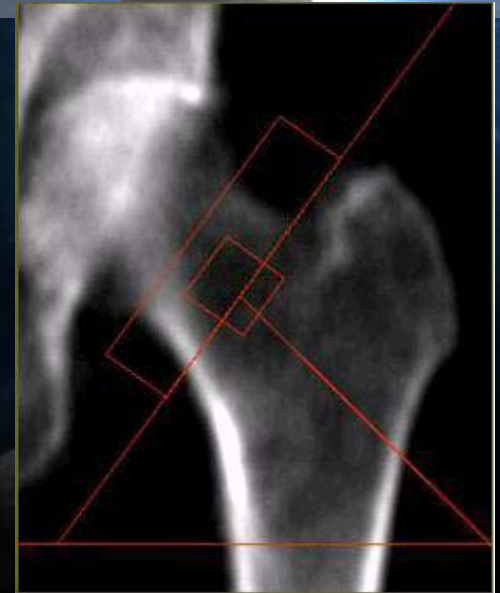
Fluid Shifts

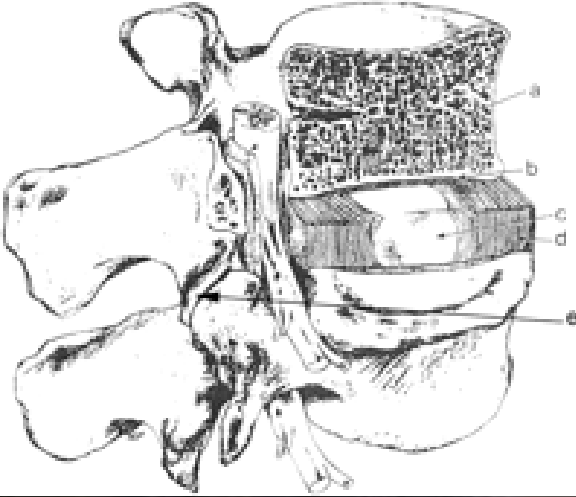


- No Gravity → No Hydrostatic Gradient
 - Puffy Faces
 - Runny Noses
 - Mild Headaches
 - “Bird Legs”
 - SAS?
- Return to 1-G:
 - Orthostatic Intolerance
 - G-suit, Fluid Loading

Musculoskeletal & Kidney

- “Antigravity” Muscles & Bones Respond to Loading History
- Without Loading in Space → Atrophy
- Also Leads to:
 - Ca^{++} kidney stones
 - Premature Osteoporosis
 - Secondary Injuries





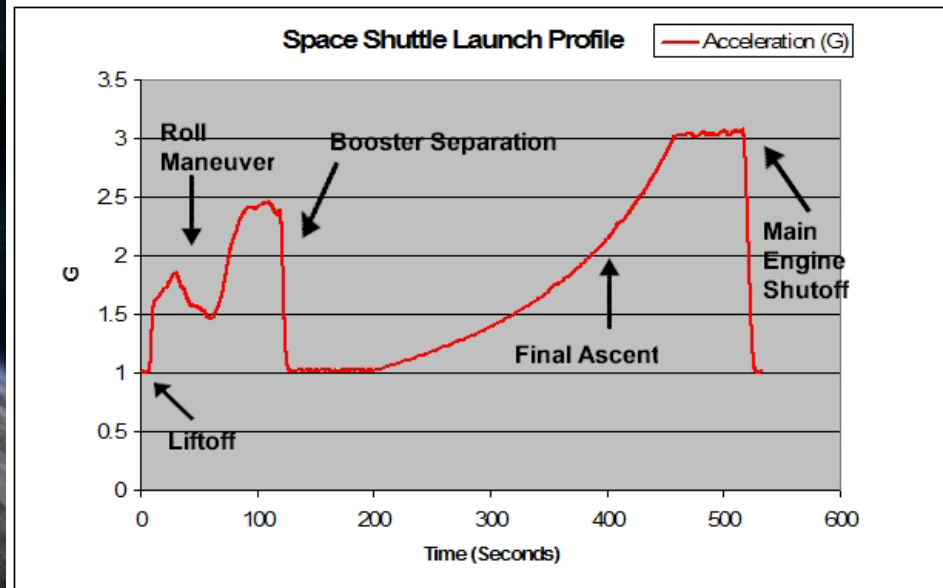
Back Pain

- Unloading Results in Intervertebral Disc Swelling
- Low Back Pain On-Orbit is Very Common
- Sleeping in Fetal Position Often Helpful
- May Predispose Astronauts to Disc Disease Later in Life



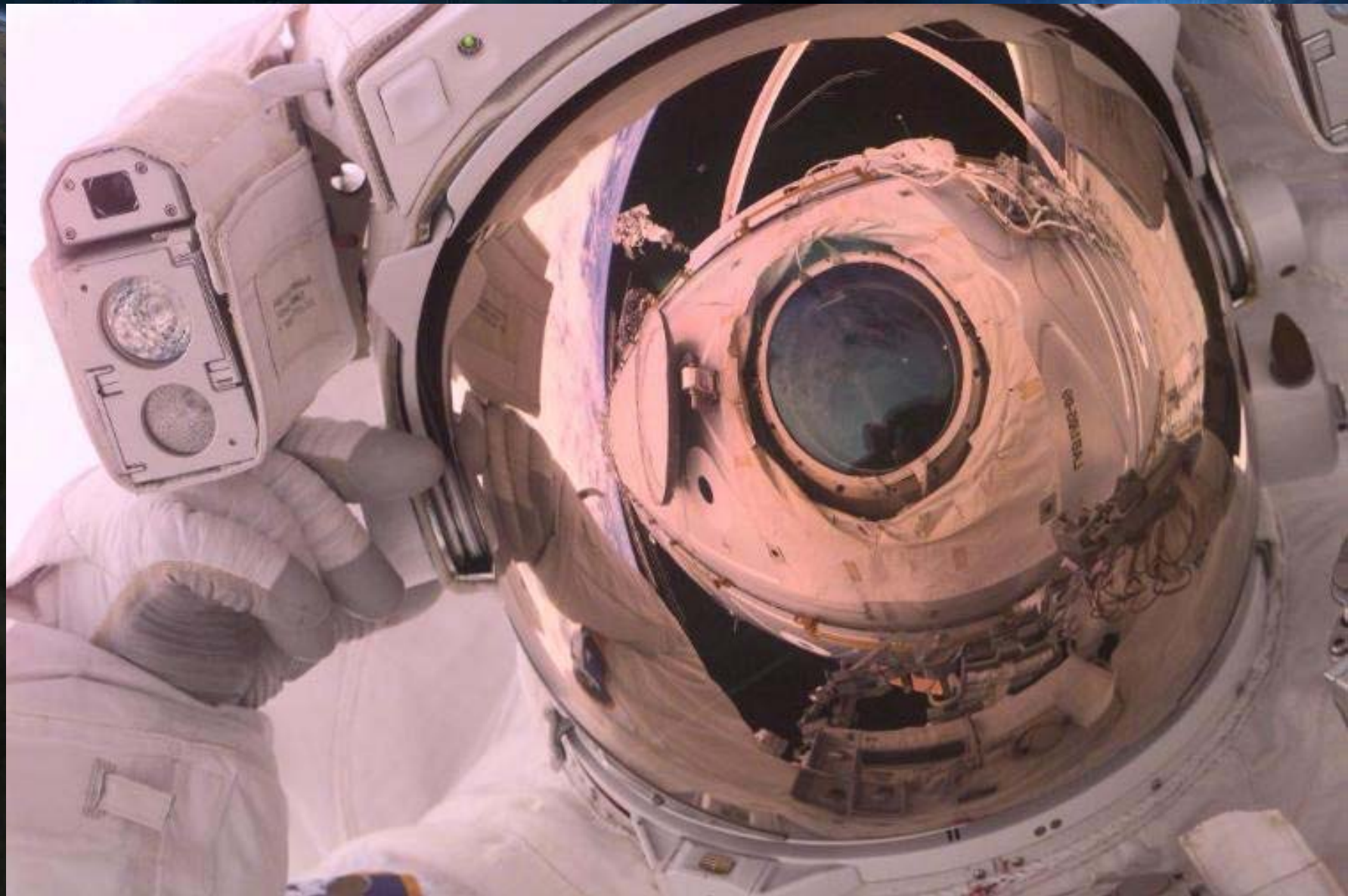
Other Aeromed Considerations

- Acceleration (“G’s”):
 - Many CSF Vehicles >> Shuttle Accelerations
- Non-Gov. Crew:
 - Older, Younger?
 - Less Medical Screening
 - More Underlying Illness?
- Urinary Retention
- Infections, ↓ Immune f(n)
- Respiratory & Eye Irritation
- Visual Acuity



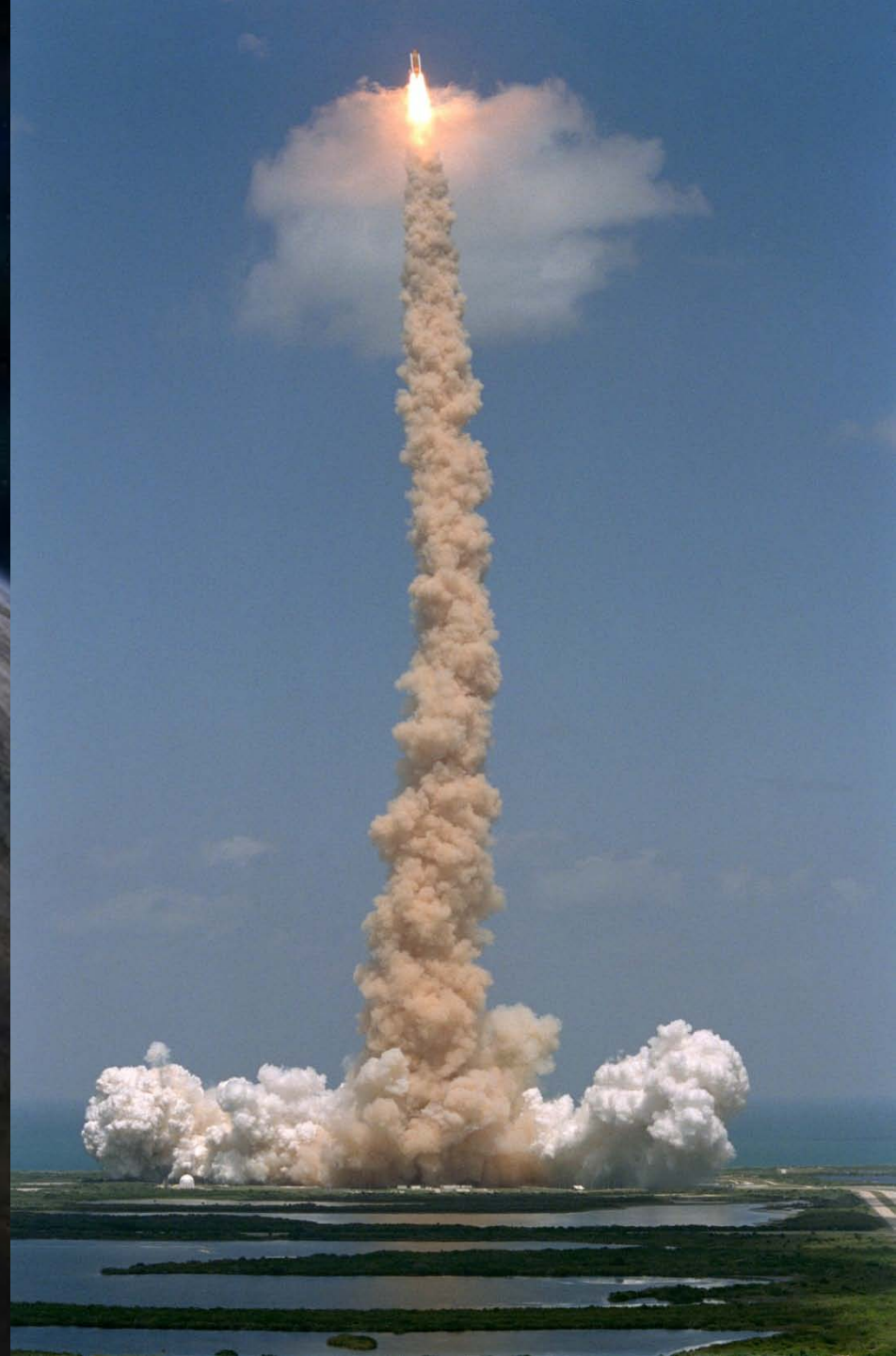
Engineering for Success

- Human Diversity & Complexity: must take into account for safe & efficient spacecraft design, development, test and flight operations
- Early Crew Involvement: pays huge dividends in all phases of development & operations
- Human Physiology and Medical Issues: are fairly well understood & should be factored into spacecraft architecture (systems, provisioning)



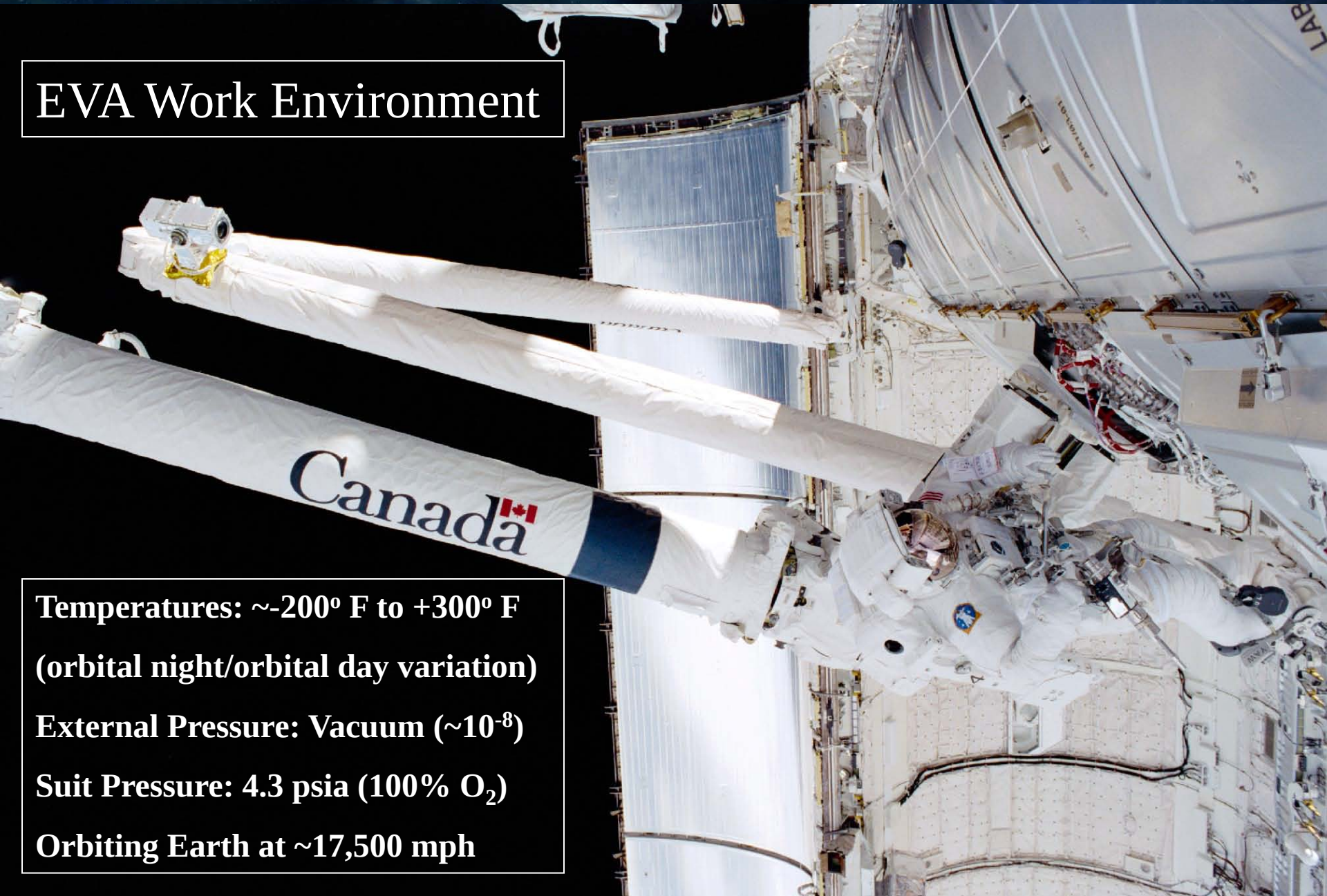
EVA: The Final Frontier

- EVA Work Environment
- Suit and Systems
- EVA Training
- EVA Physiology
- EVA Risks
- EVA Injury
- Injury Prevention & Rx
- The Future of Space Exploration: BEO EVA



EVA Work Environment

**Temperatures: $\sim -200^{\circ}\text{F}$ to $+300^{\circ}\text{F}$
(orbital night/orbital day variation)**
External Pressure: Vacuum ($\sim 10^{-8}$)
Suit Pressure: 4.3 psia (100% O_2)
Orbiting Earth at $\sim 17,500$ mph



EVA Job Description

- 6-8 hour spacewalks the norm
- Often very confining workspaces
- Physically demanding: upper body strength and endurance
- Work often requires great precision/tactility/dexterity
- Best view in the Universe!

EMU Work Envelope

95th% crewmembers
optimal work envelope
to be used as the optimum
one-handed work envelope

26 in. Dia

16 in. Dia

18 in.

13 in.

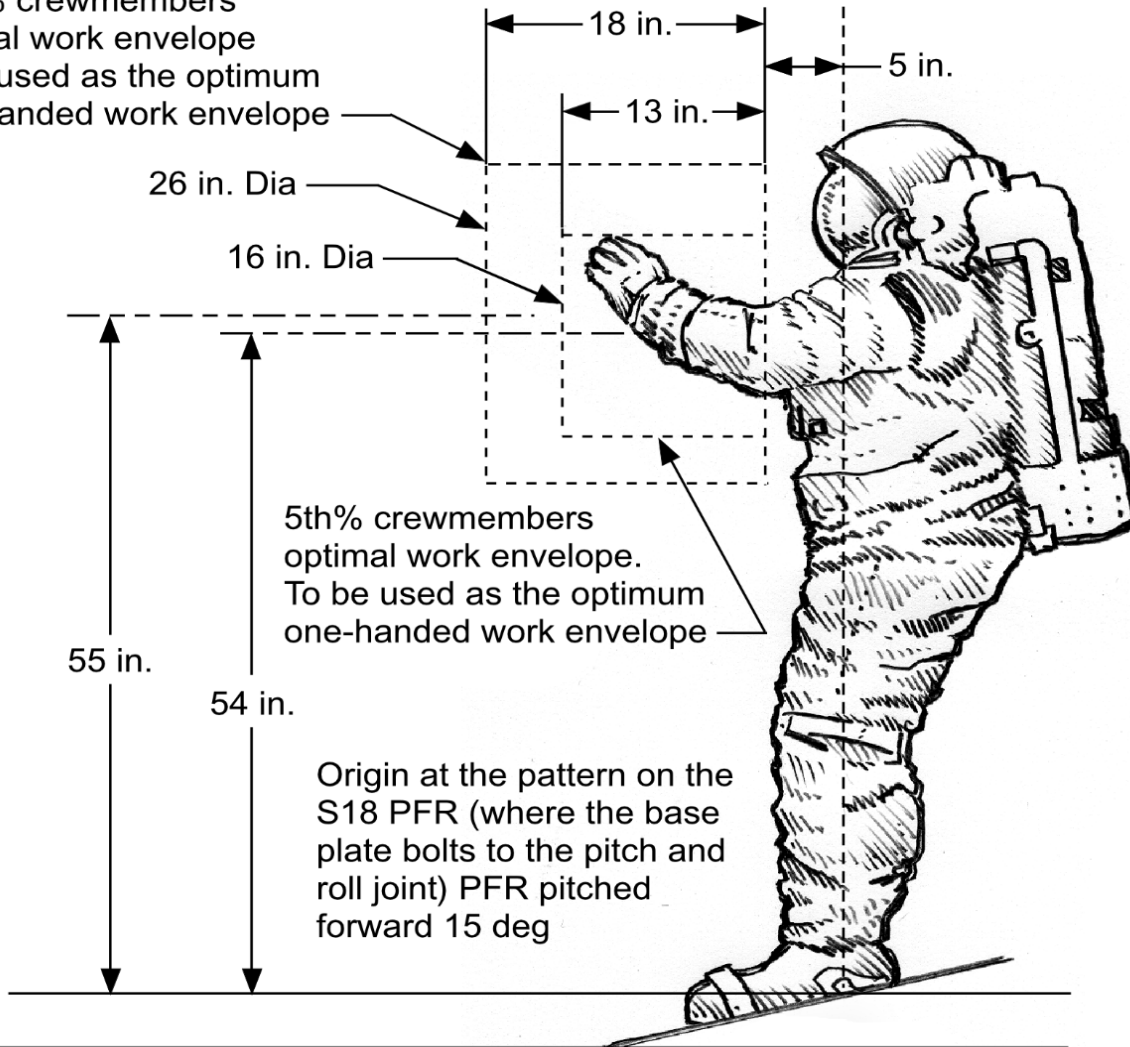
5 in.

5th% crewmembers
optimal work envelope.
To be used as the optimum
one-handed work envelope

55 in.

54 in.

Origin at the pattern on the
S18 PFR (where the base
plate bolts to the pitch and
roll joint) PFR pitched
forward 15 deg





EMU: a personal spacecraft

Extravehicular Mobility Unit

- Protection from vacuum, temperature extremes, orbital debris
- Communications with crew, MCC
- Active cooling/passive heating
- Biomedical monitoring (ECG, passive dosimetry)
- Video monitoring
- Tool platform/storage
- Drinking water (no food)
- Oxygen delivery (with b/u)
- CO2 scrubbing
- EMU “health monitoring”
- Propulsion (“Simplified Aid for EVA Rescue”)



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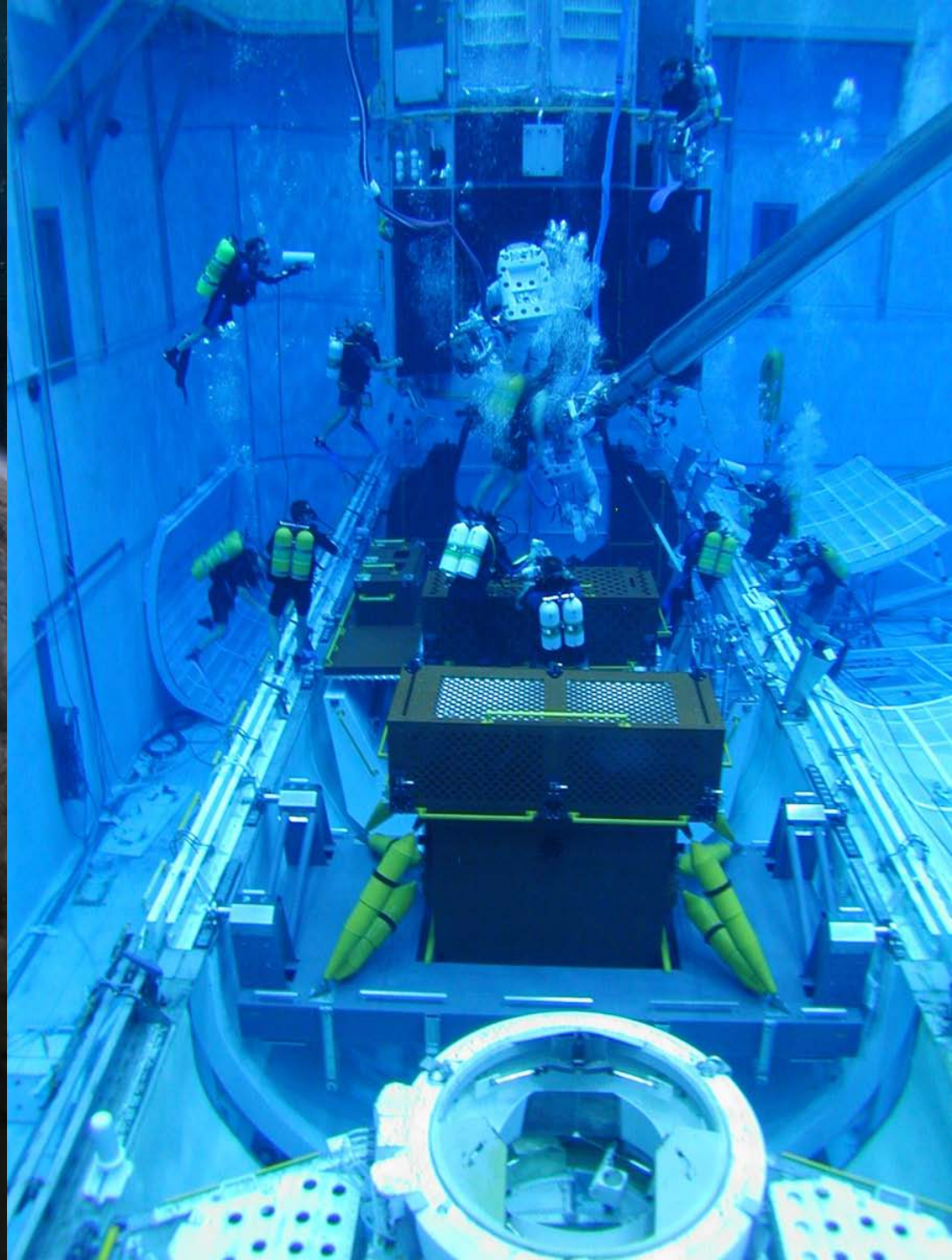


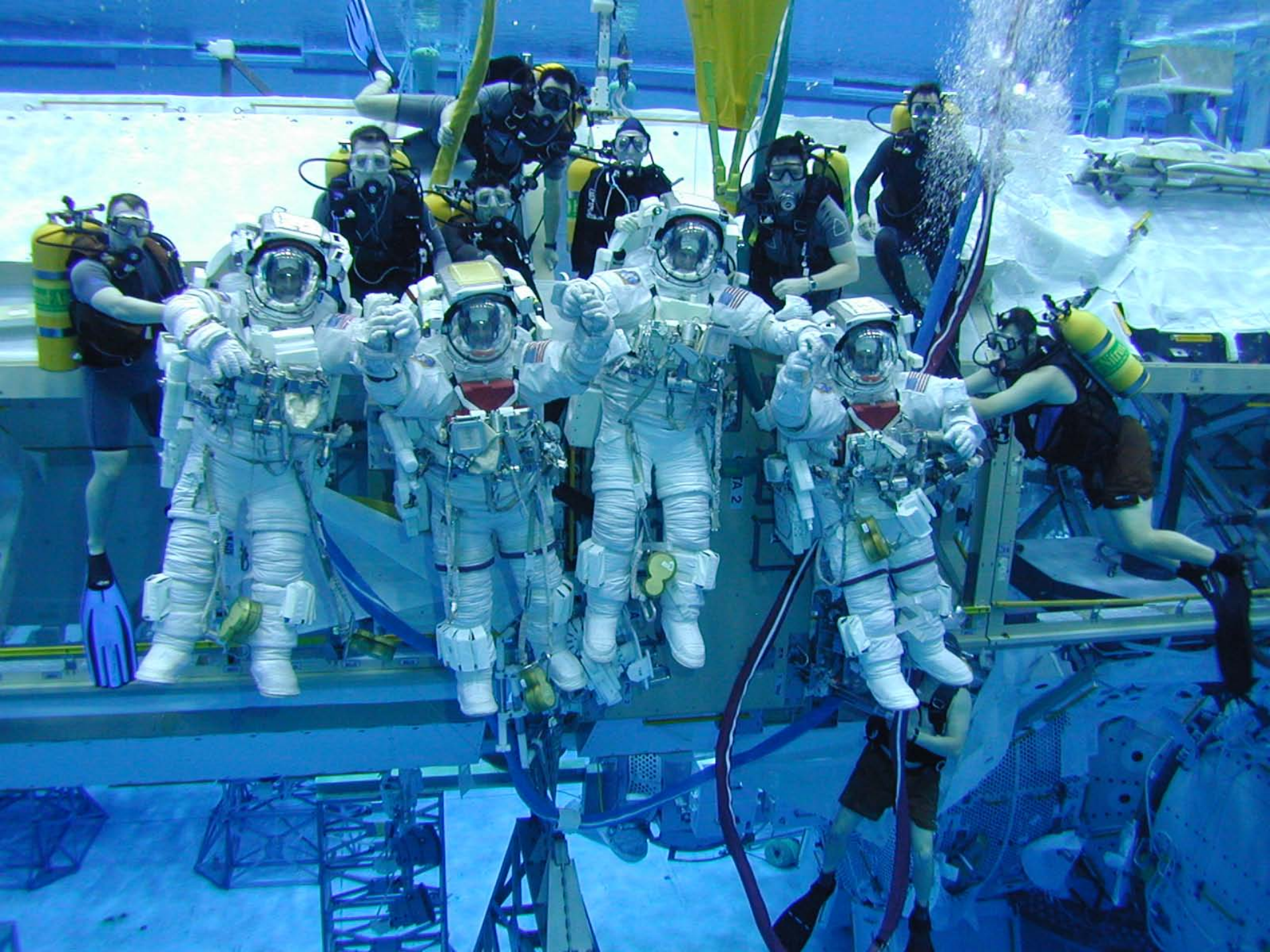
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EVA Training Environments

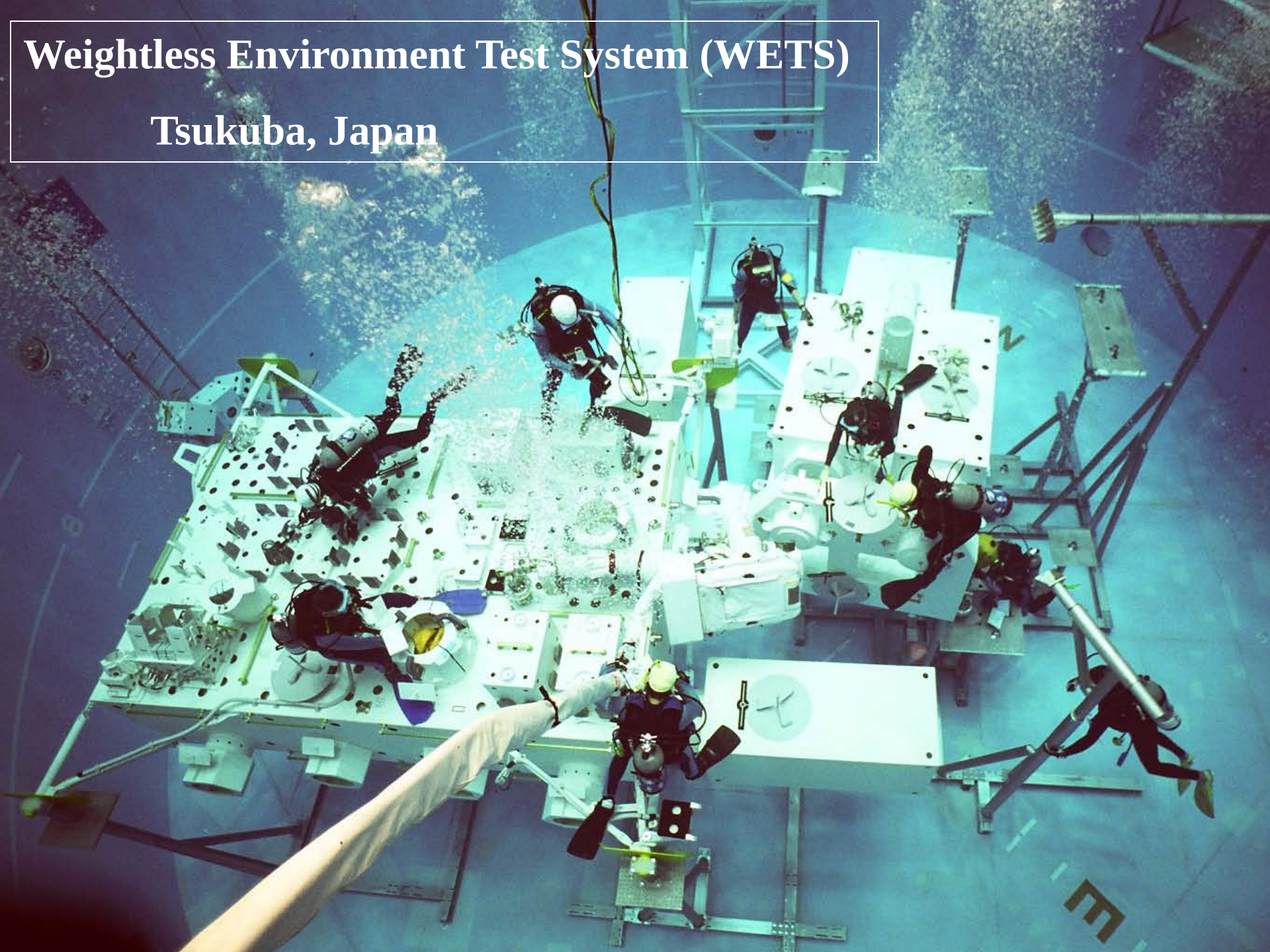
- Neutral buoyancy facilities
 - Choreograph timelines
 - Integrate EVA-robotics
 - 0-G analog (water drag a major difference)
 - Nitrox used to increase bottom time
- Virtual Reality Lab
- Air Bearing Floor
- Vacuum Chambers
- EMU Systems Simulations
- Integrated Simulations with Mission Control
- The Gym!

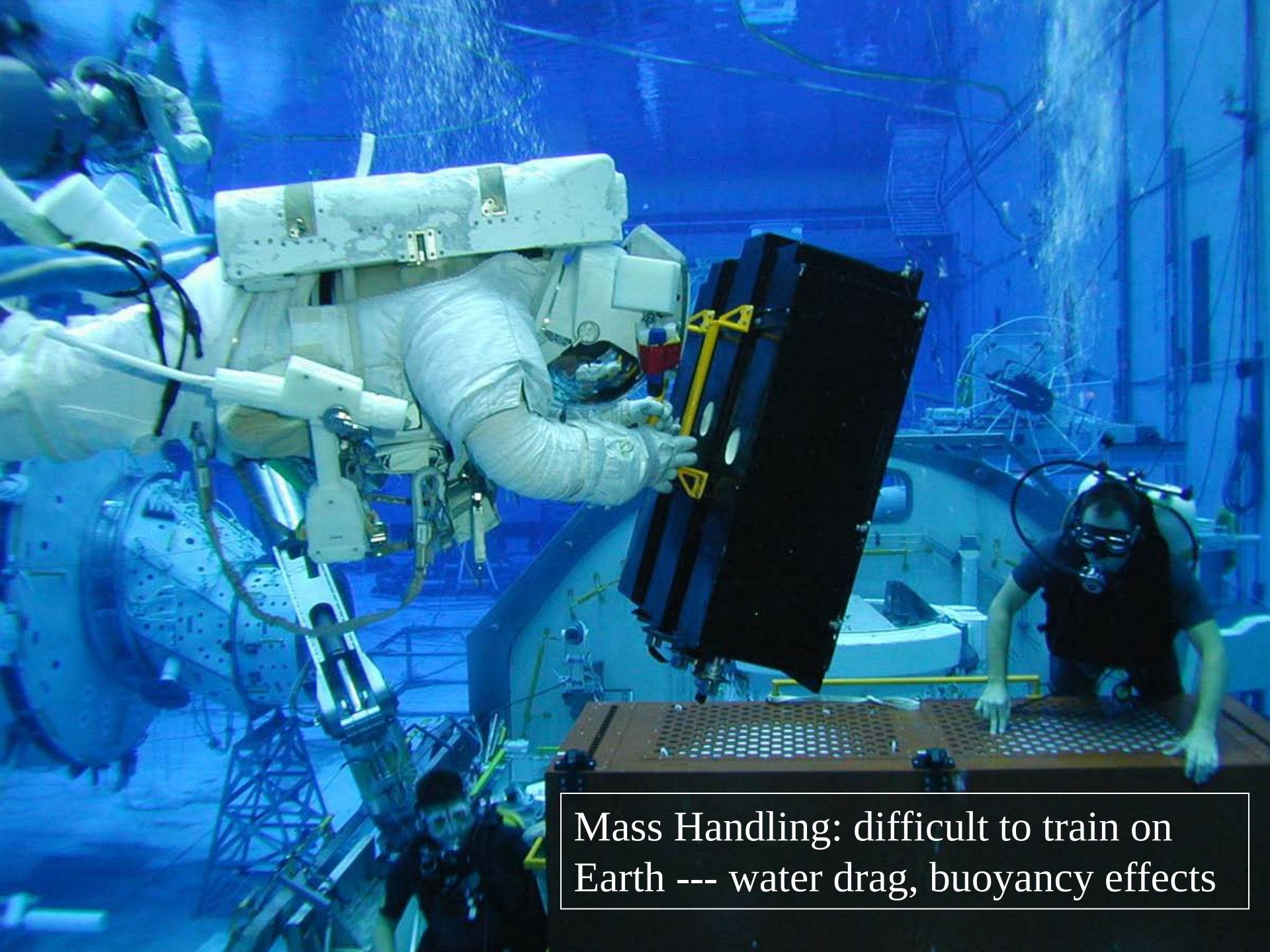




Weightless Environment Test System (WETS)

Tsukuba, Japan





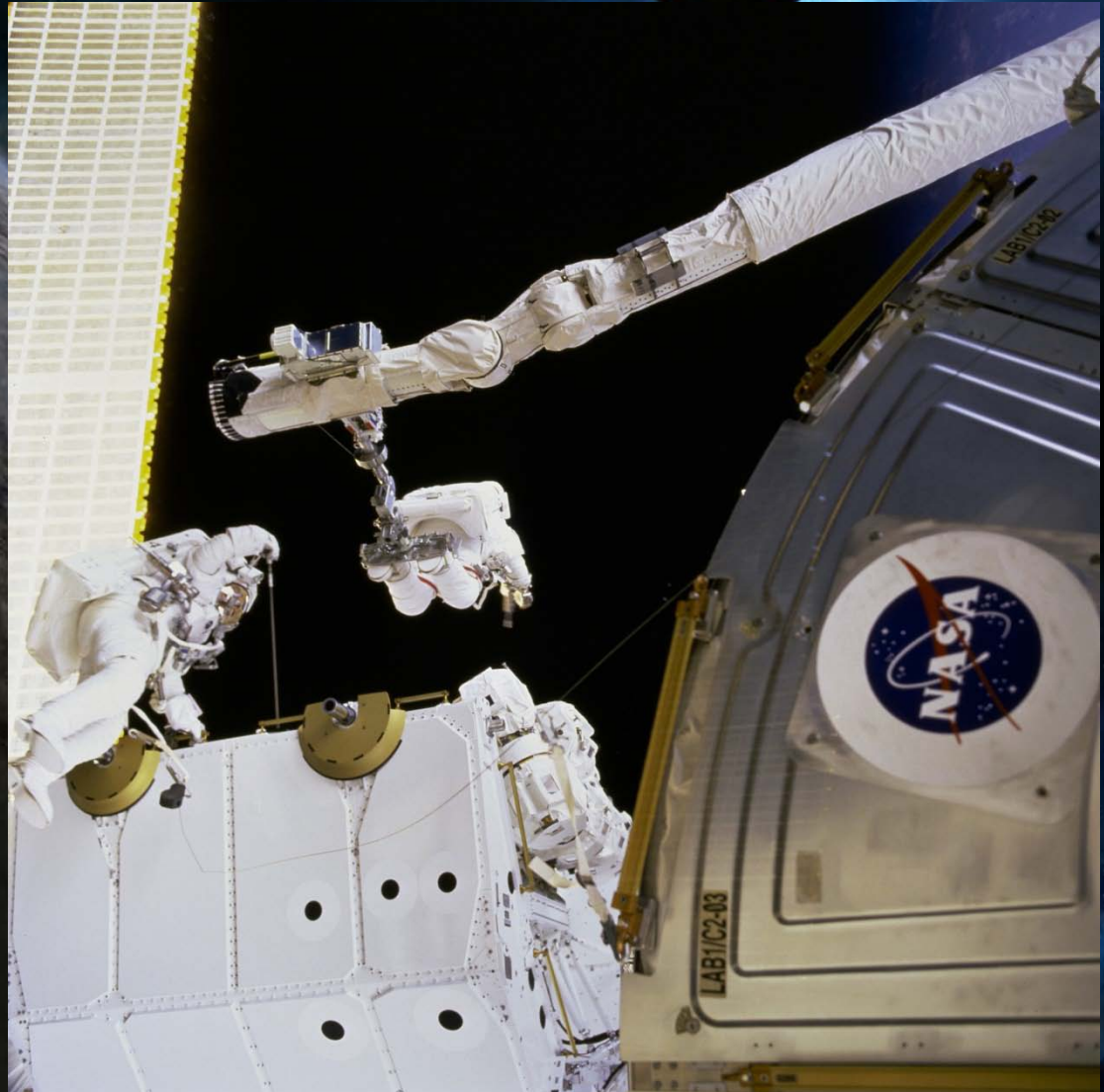
Mass Handling: difficult to train on Earth --- water drag, buoyancy effects

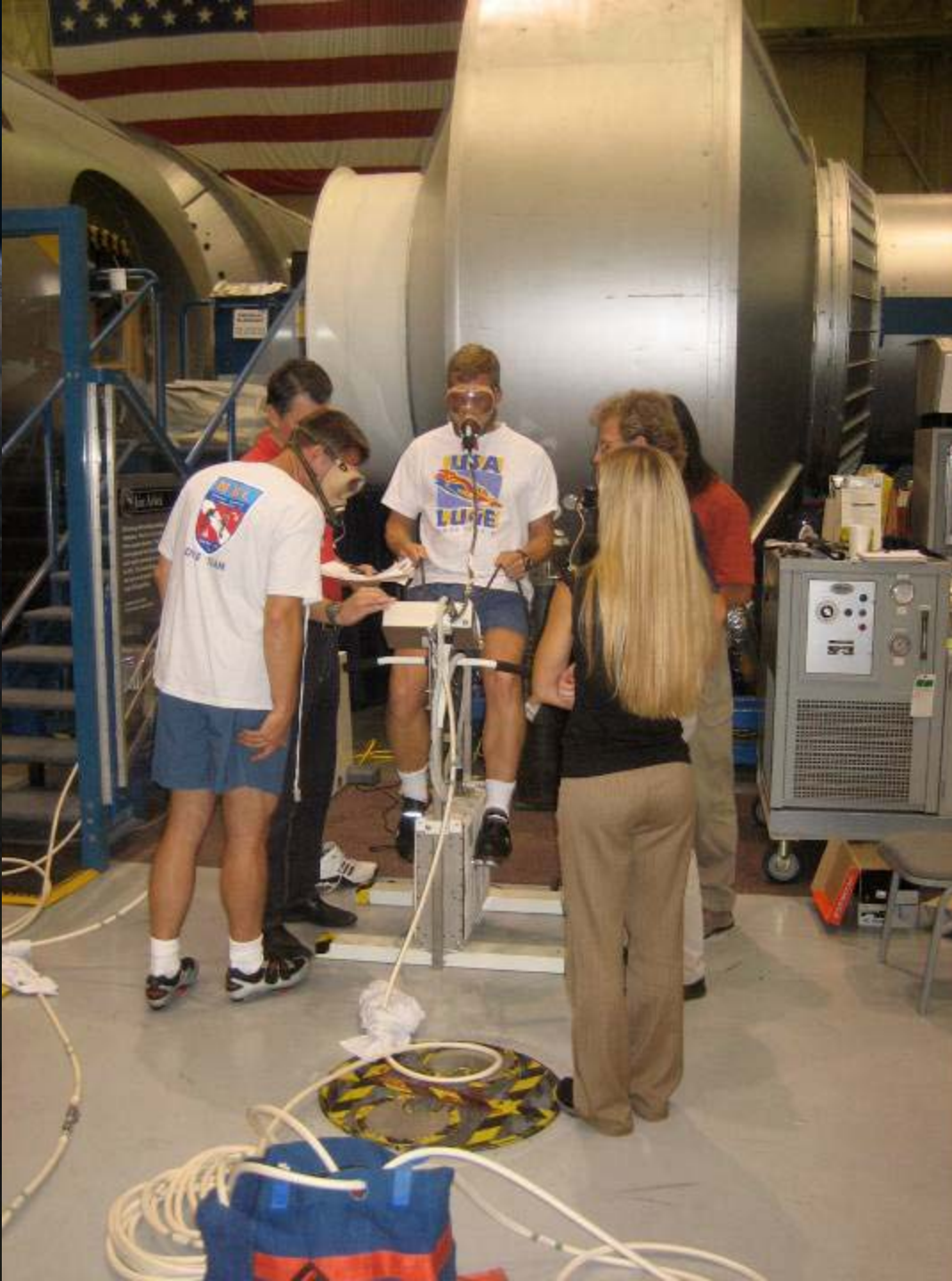


Unusual Training Attitudes: risk of shoulder injuries --- simple bruises to rotator cuff tears; barotrauma; orthostatic intolerance; disorientation

EVA Physiology:

- Pressure changes with similarity to diving → risk of DCS and barotrauma (during both real and simulated EVA)
- EVA preparations: 4 hour in-suit prebreathe on 100% oxygen, “campout,” or exercise prebreathe protocol
- Incidence of DCS in space << diving DCS

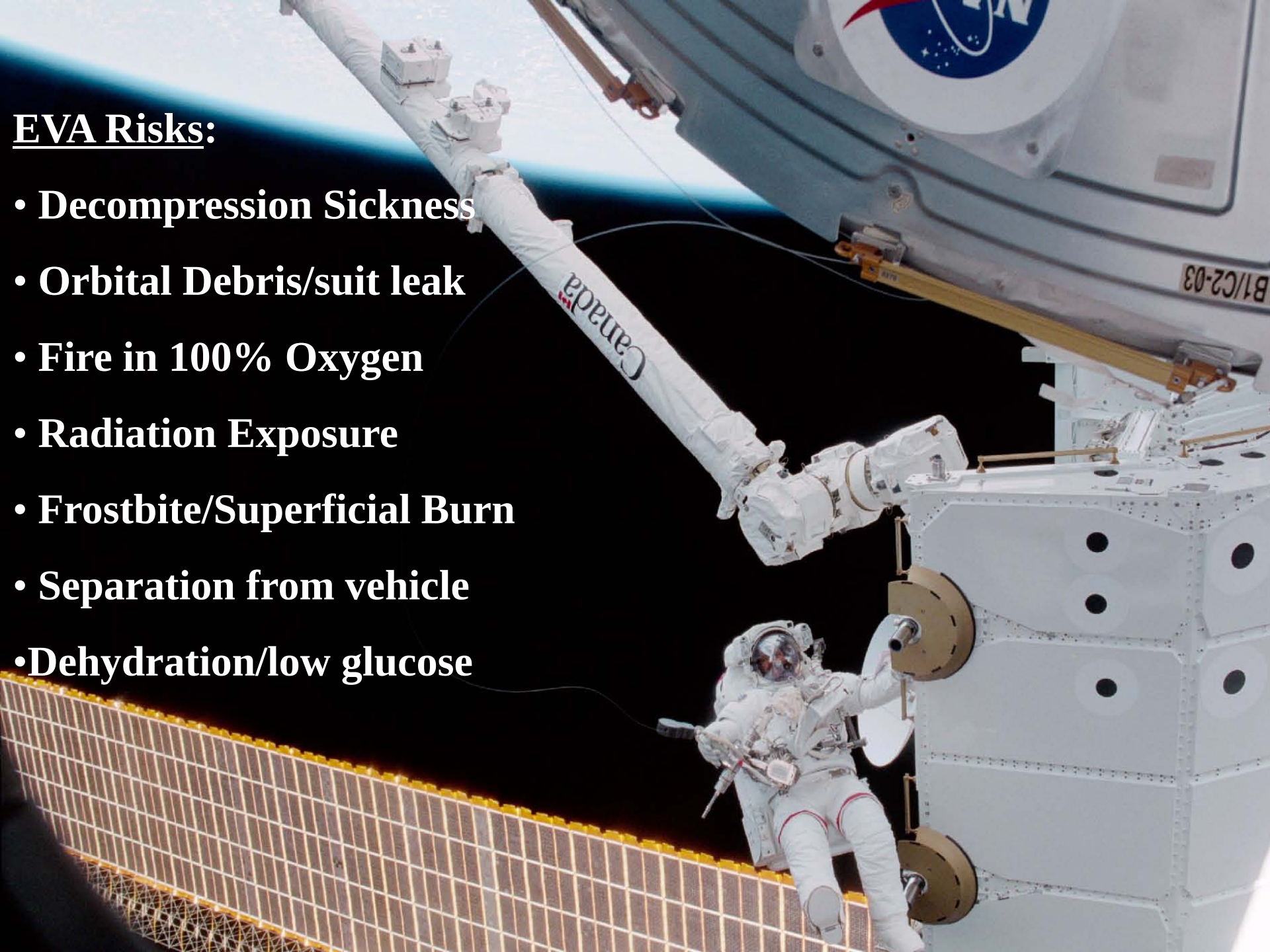






EVA Risks:

- Decompression Sickness
- Orbital Debris/suit leak
- Fire in 100% Oxygen
- Radiation Exposure
- Frostbite/Superficial Burn
- Separation from vehicle
- Dehydration/low glucose



EVA Injuries:

- Nerve Compression; Foot Pain, other hot spots
- Shoulder Injuries:
 - Rotator Cuff Tears
 - Superior Labral Tear from Anterior to Posterior (SLAP)
 - Tendonitis/Bursitis
- Fingernail Delamination
- Eye Irritation
- Barotrauma
- Orthostatic Intolerance
- DCS (Type 1 and Type 2)



Injury Prevention/Rx:

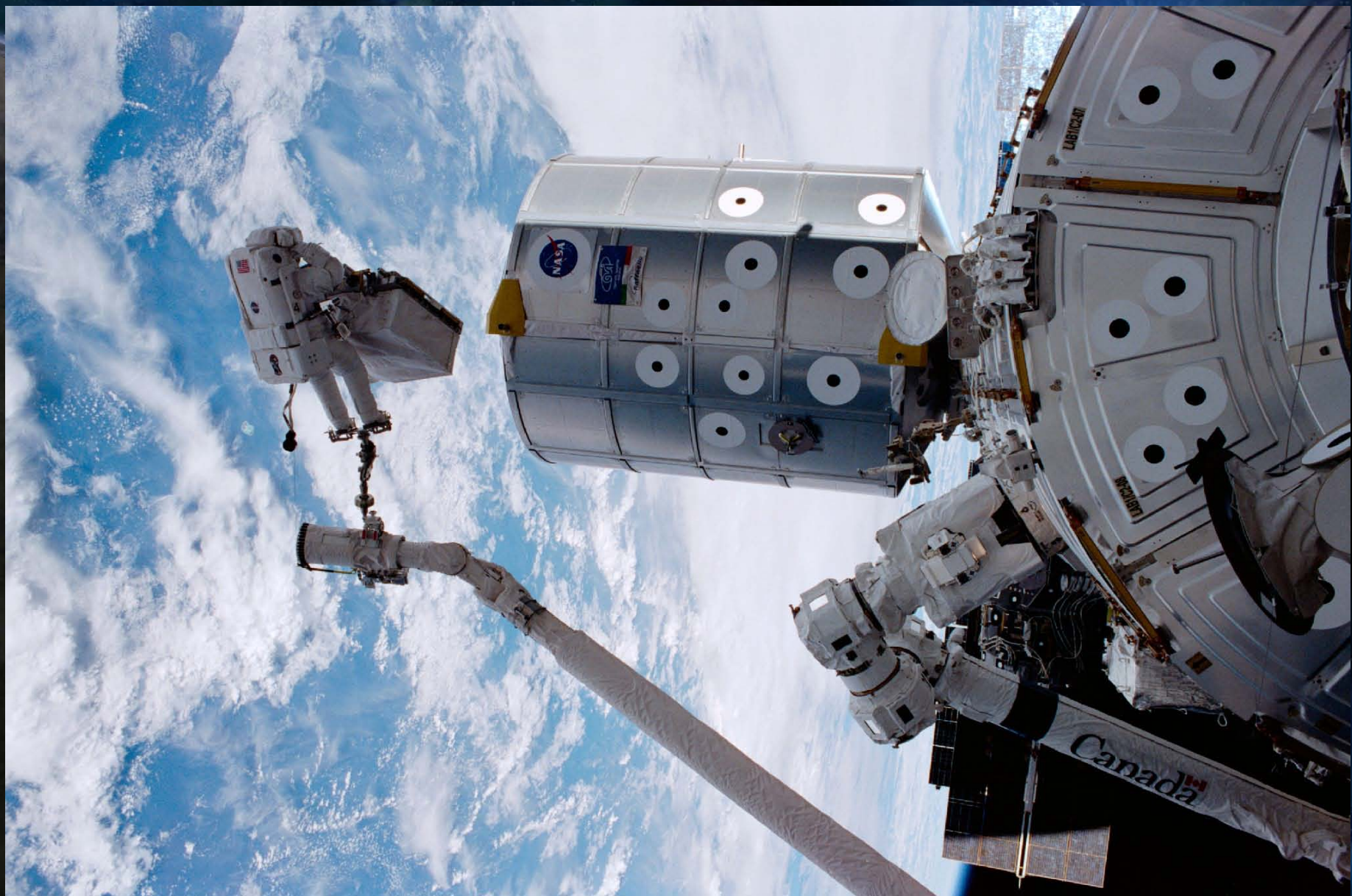
- Optimum Suit Fit
- Preflight Conditioning
- Avoiding Prolonged Inverted Ops (pool)
- Proper Fingernail Care (trim, keep dry); Custom Gloves; Glue
- Knowledge of and Working within the Work Envelope of the Planar Hard Upper Torso (HUT)
- Prebreathe, Bends Treatment Adapter for DCS



Strength & Conditioning

- Key element to flight preparation
- Injury prevention
- Development of strength and endurance --- especially important for forearm, wrist and hand intrinsics
- Strength and Conditioning coaches work directly with crew; mandatory for EVA crewmembers to exercise 3x/week
- Also important: flexibility and aerobic capacity

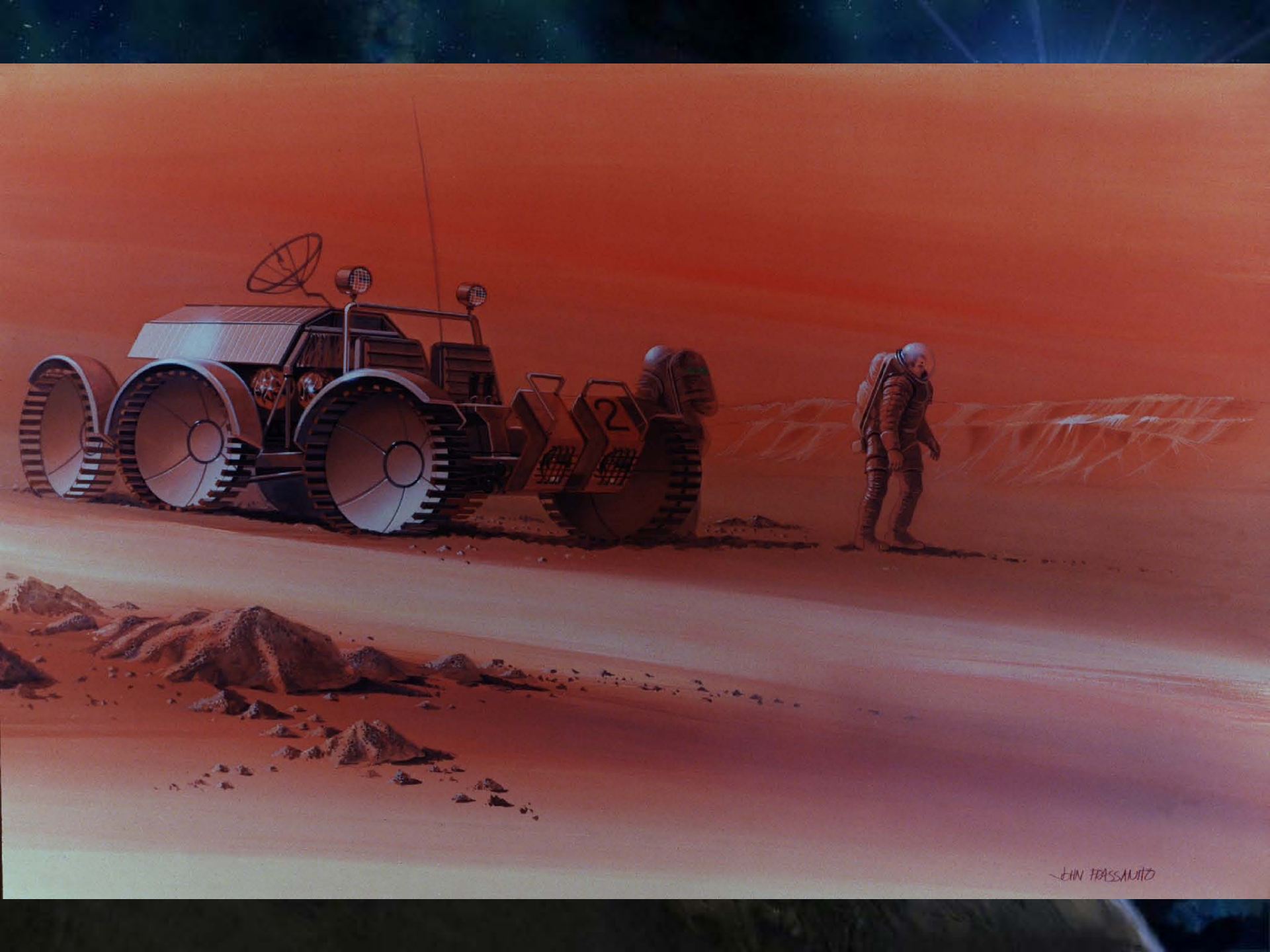




Miscellaneous:

- Astronauts are physically very active; some have preexisting orthopedic injuries; some get hurt before flight (softball!)
- Size and strength an asset because of physical nature of the job; difficult to scale gloves to smaller sizes
- Flying after diving is often required; special tables for Nitrox have been developed for our use
- Russian “Orlan” suit used on ISS --- 5.7 psia





~BIN FRASSALITO

Implications for BEO

- Planetary EVA $\neq$ LEO EVA $\neq$ Asteroid EVA
- Planetary EVA Considerations:
 - Center of Mass
 - Ground Reaction Force
 - Dust
- Asteroid EVA Considerations:
 - “Microgravity Geology”
 - Newton’s Laws
- Need to ↓ ops overhead



QUESTIONS/DISCUSSION



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